Adaptive Control of Cutting Force for End Milling Processes

Motivation

- Fixed controllers are designed for nominal plants and effectiveness diminishes as the cutting parameters vary.
- Varying gains and dynamics require conservative feedrate settings for fixed control systems
- Maintaining desired cutting forces prolongs tool life increasing productivity
- Standard MRAC has the following limitations:
  - Introduces instability for nonminimum phase zeros
  - Large input signal oscillation possible

Approaches:

- Develop an adaptive control scheme to maintain constant cutting force during end milling for time-varying cutting conditions.
- Augment the performance index of the controller to reduce input signal oscillation.
- Implement the adaptive control scheme on a high speed milling machine through a PC-based open architecture.

Results:

- An adaptive controller has been designed that will maintain a constant cutting force for milling operations by controlling the feedrate of the table.
- Extended MRAC designs offer an improvement over the Standard MRAC system in its ability to control nonminimum phase plants.
- Augmented Performance Index can effectively reduce input oscillation which is detrimental to machine life.
- A PC based open architecture controller was designed to control CNC machines, thus allowing the testing of new algorithms.
- Experimental implementation was performed using a workpiece containing two changes in the axial depth of cut (Figure 2). While machining with a fixed parameter controller showed step changes in cutting force due to the depth of cut changes (Figure 3), the tests performed with the developed adaptive controller for various radial depths of cut under varying machining conditions produced constant cutting force (Figure 4).

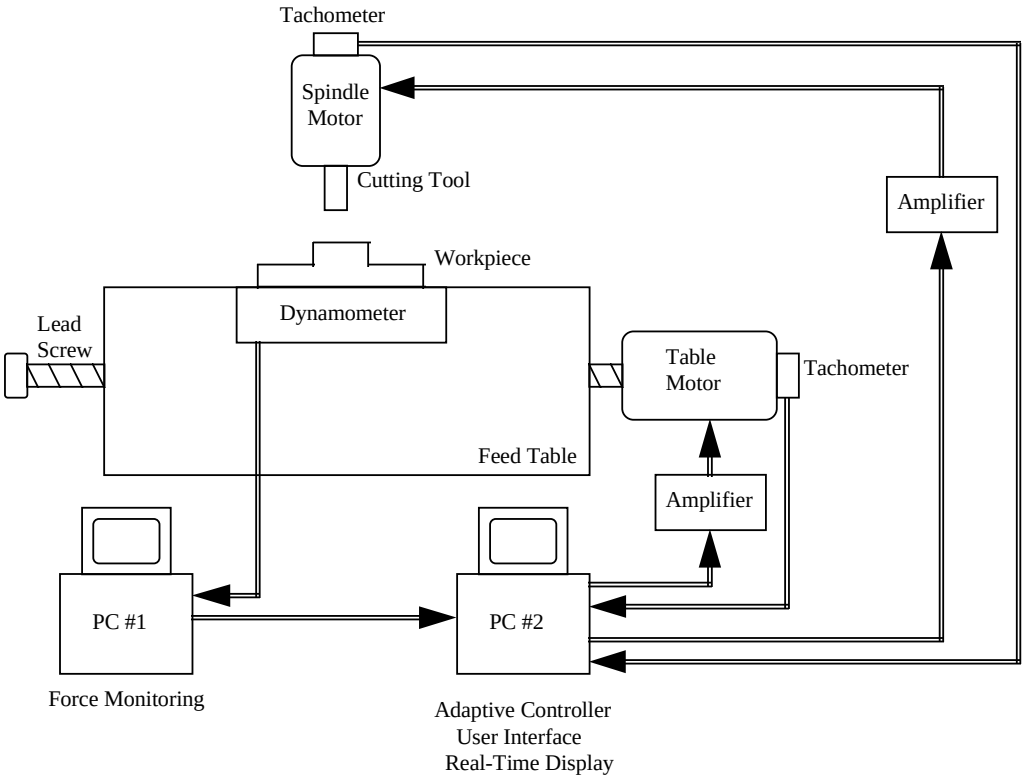


Figure 1. Experimental set for adaptive cutting force control on a high speed milling machine.

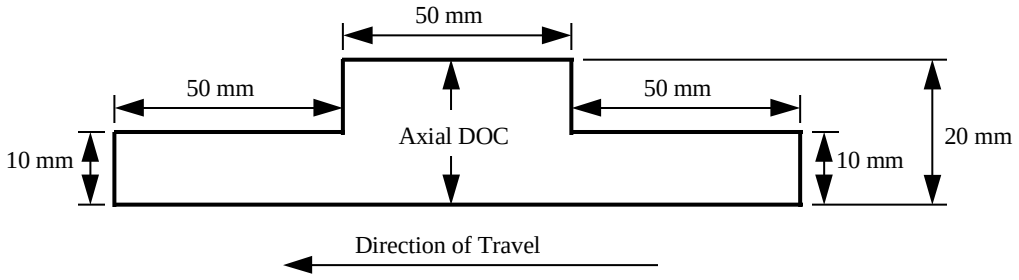
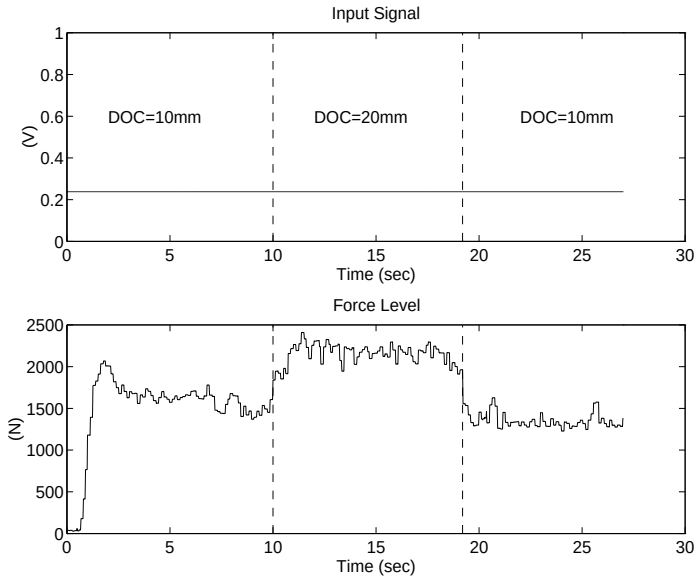


Figure 2 - Cross Section of Workpiece Used in End Milling Experiments



Overshoot: 30 %, Settling Time: 3 Seconds
Sampling Period: 20ms, Cutter Speed: 1500rpm

Figure 3. Constant input force response without adaptive control.

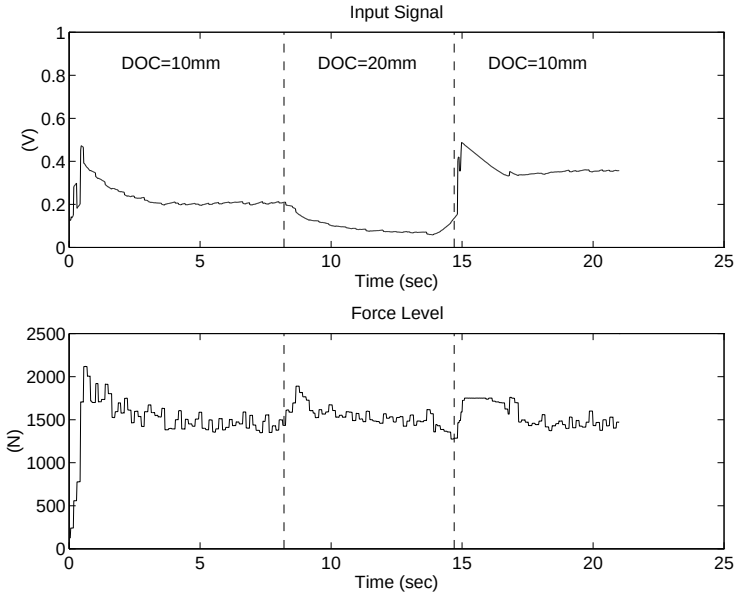


Figure 4. Input signal and force level with the adaptive controller
(0.080" DOC, W=10,000)